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vented by Edward Wright about the year 1600. Each of these, as a particular case of the orthomorphic projection, belongs to the theory of the geometrical representation of an imaginary variable. I have spoken also of perspective, and (in an omitted paragraph) of the representation of solid figures employed in Monge's descriptive geometry. Monge, it is, well known, is the author of the geometrical theory of the curvature of surfaces, and of curves of curvature. He was led to this theory by a problem of earthwork, — from a given area, covered with earth of uniform thickness, to carry the earth and distribute it over an equal given area with the least amount of cartage. For the solution of the corresponding problem in solid geometry, he had to consider the intersecting normals of a surface, and so arrived at the curves of curvature (see his '*Mémoire sur les déblais et les remblais*,' *Mém. de l'acad.*, 1781). The normals of a surface are, again, a particular case of a doubly infinite system of lines, and are so connected with the modern theories of congruences and complexes.

The undulatory theory of light led to Fresnel's wave-surface, — a surface of the fourth order, by far the most interesting one which had then presented itself. A geometrical property of this surface, that of having tangent planes, each touching it along a plane curve (in fact, a circle), gave to Sir W. R. Hamilton the theory of conical refraction. The wave-surface is now regarded in geometry as a particular case of Kummer's quartic surface, with sixteen conical points and sixteen singular tangent planes.

My imperfect acquaintance, as well with the mathematics as the physics, prevents me from speaking of the benefits which the theory of partial differential equations has received from the hydrodynamical theory of vortex motion, and from the great physical theories of electricity, magnetism, and energy.

It is difficult to give an idea of the vast extent of modern mathematics. This word 'extent' is not the right one: I mean extent crowded with beautiful detail, — not an extent of mere uniformity, such as an objectless plain, but of a tract of beautiful country seen at first in the distance, but which will bear to be rambled through, and studied in every detail of hillside and valley, stream, rock, wood, and flower. But as for any thing else, so for a mathematical theory, — beauty can be perceived, but not explained. As for mere extent, I might illustrate this by speaking of the dates at which some of the great extensions have been made in several branches of mathematical science.

And, in fact, in the address as written, I speak at considerable length of the extensions in geometry since the time of Descartes, and in other specified subjects since the commencement of the century. These subjects are the general theory of the function of an imaginary variable; the leading known functions, viz., the elliptic and single theta-functions and the Abelian and multiple theta-functions; the theory of equations and the theory of numbers. I refer also to some theories outside of ordinary mathematics, — the multiple algebra, or linear associative algebra, of the late Benjamin Peirce; the theory of Argand, War-

ren, and Peacock, in regard to imaginaries in plane geometry; Sir W. R. Hamilton's quaternions; Clifford's biquaternions; the theories developed in Grassmann's '*Ausdehnungslehre*,' with recent extensions thereof to non-Euclidian space by Mr. Homersham Cox; also Boole's '*Mathematical logic*,' and a work connected with logic, but primarily mathematical and of the highest importance, Shubert's '*Abzählende geometrie*' (1878). I remark that all this in regard to theories outside of ordinary mathematics is still on the text of the vast extent of modern mathematics.

In conclusion, I would say that mathematics have steadily advanced from the time of the Greek geometers. Nothing is lost or wasted. The achievements of Euclid, Archimedes, and Apollonius, are as admirable now as they were in their own days. Descartes' method of co-ordinates is a possession forever. But mathematics has never been cultivated more zealously and diligently, or with greater success, than in this century, — in the last half of it, or at the present time. The advances made have been enormous. The actual field is boundless, the future full of hope. In regard to pure mathematics we may most confidently say, —

"Yet I doubt not through the ages one increasing purpose runs,
And the thoughts of men are widened with the process of the
suns."

THE ENDOWMENT OF BIOLOGICAL RESEARCH.¹

It has become the custom for the presidents of the various sections of this association to open the proceedings of the departments with the chairmanship of which they are charged by formal addresses. In reflecting on the topics which it might be desirable for me to bring under your notice, as your president, on the present occasion, it has occurred to me that I might use this opportunity most fitly by departing somewhat from the prevailing custom of reviewing the progress of science in some special direction during the past year, and that, instead of placing before you a summary of the results recently obtained by the investigations of biologists in this or that line of inquiry, I might ask your attention, and that of the external public (who are wont to give some kindly consideration to the opinions expressed on these occasions) to a matter which is even more directly connected with the avowed object of our association; namely, 'the advancement of science.' I propose to place before you a few observations upon the provision which exists in this country for the advancement of that branch of science to which section D is dedicated; namely, biology.

I am aware that it is usual for those who speak of men of science and their pursuits to ignore altogether such sordid topics as the one which I have chosen to bring forward. A certain pride, on the one hand, and a willing acquiescence, on the other hand, usually prevent those who are professionally concerned with

¹ An address to the biological section of the British association. By Prof. E. Ray Lankester, M.A., F.R.S., F.L.S., president of the section. From advance copy kindly furnished by the editor of *Nature*.

scientific pursuits from exposing to the public the pecuniary destitution, and the consequent crippling and languor, of scientific research in this country. Those Englishmen who take an interest in the progress of science are apt to suppose, that, in some way which they have never clearly understood, the pursuit of scientific truth is not only its own reward, but also a sufficient source of food, drink, and clothing. Whilst they are interested and amused by the remarkable discoveries of scientific men, they are astonished whenever a proposal is mentioned to assign salaries to a few such persons, sufficient to enable them to live decently whilst devoting their time and strength to investigation. The public are becoming more and more anxious to have the opinion or report of scientific men upon matters of commercial importance, or in relation to the public health; and yet, in ninety-nine cases out of a hundred, they expect to have that opinion for the asking, although accustomed to pay other professional men handsomely for similar service. There is, it appears, in the public mind, a vague belief that men who occupy their time with the endeavor to add to knowledge in this or that branch of science are mysteriously supported by the state exchequer, and are thus fair game for attacking with all sorts of demands for gratuitous service; or, on the other hand, the notion at work appears sometimes to be, that the making of new knowledge — in fact, scientific discovery — is an agreeable pastime, in which some ingenious gentlemen, whose business in other directions takes up their best hours, find relaxation after dinner or on the spare hours of Sunday. Such mistaken views ought to be dispelled with all possible celerity and determination. It is in part owing to the fact that the real state of the case is not widely and persistently made known to the public, that no attempt is made in this country to raise scientific research, and especially biological research, from the condition of destitution and neglect under which it suffers, — a condition which is far below that of these same interests in France and Germany, and even in Holland, Belgium, Italy, and Russia, and is discreditable to England in proportion as she is richer than other states.

It appears to me, that, in placing this matter before you, I may remove myself from any suggestion of self-interest by at once stating that the great defect to which I shall draw your attention is, *not* that the few existing public positions which are open in this country to men who intend to devote their chief energies to biological research are endowed with insufficient salaries, but that there is not any thing like *a sufficiently large number* of those posts, and that there is in that respect, from a national point of view, a pecuniary starvation of biology, a withholding of money, which (to use another metaphor) is no less the sinews of the war of science against ignorance than of other less glorious campaigns. Surely, men engaged in the scientific profession may advocate the claim of science to maintenance and needful pecuniary provision. It seems to me that we should, if necessary, swallow, rather than be controlled by, that

pride which tempts us to paint the scientific career as one far above and independent of pecuniary considerations; whereas all the while we know that knowledge is languishing, that able men are drawn off from scientific research into other careers, that important discoveries are approached and their final grasp relinquished, that great men depart, and leave no disciples or successors, simply for want of that which is largely given in other countries, — of that which is most abundant in this country, and is so lavishly expended on armies and navies, on the development of commercial resources, on a hundred injurious or meaningless charities, — viz., money.

I have no doubt that I have the sympathy of all my hearers in wishing for more extensive provision in this country for the prosecution of scientific research, and especially of biological research. I need hardly remind this audience of the almost romantic history of some of the great discoveries which have been made in reference to the nature and history of living things during the past century. The microscope, which was a drawing-room toy a hundred years ago, has, in the hands of devoted and gifted students of nature, been the means of giving us knowledge which, on the one hand, has saved thousands of surgical patients from terrible pain and death, and, on the other hand, has laid the foundation of that new philosophy with which the name of Darwin will forever be associated. When Ehrenberg, and, later, Dujardin, described and figured the various forms of *Monas*, *Vibrio*, *Spirillum*, and *Bacterium*, which their microscopes revealed to them, no one could predict that fifty years later these organisms would be recognized as the cause of that dangerous suppurative of wounds which so often defeated the beneficent efforts of the surgeon, and made an operation in a hospital-ward as dangerous to the patient as residence in a plague-stricken city. Yet this is the result which the assiduous studies of the biologists, provided with laboratories and maintenance by continental states, have in due time brought to light. Theodore Schwann, professor at Liège, first showed that these bacteria are the cause of the putrefaction of organic substances; and subsequently, the French chemist Pasteur, professor in the *École normale* of Paris, confirmed and extended Schwann's discovery, so as to establish the belief that all putrefactive changes are due to such minute organisms, and that, if these organisms can be kept at bay, no putrefaction can occur in any given substance.

It was reserved for our countryman, Joseph Lister, to apply this result to the treatment of wounds, and, by his famous antiseptic method, to destroy by means of special poisons the putrefactive organisms which necessarily find their way into the neighborhood of a wound, or of the surgeon's knife and dressings, and to ward off by similar means the access of such organisms to the wounded surface. The amount of death, not to speak of the suffering short of death, which the knowledge of bacteria gained by the microscope has thus averted, is incalculable.

Yet, further, the discoveries of Ehrenberg, Schwann, and Pasteur, are bearing fruit of a similar kind in

other directions. It seems in the highest degree probable that the terrible scourge known as tubercular consumption, or phthisis, is due to a parasitic bacterium (*Bacillus*) discovered two years since by Koch of Berlin as the immediate result of investigations which he was commissioned to carry on at the public expense, in the specially erected laboratory of public health, by the German imperial government. The diseases known as erysipelas and glanders (or farcy) have similarly, within the past few months in German state-supported laboratories, been shown to be due to the attacks of special kinds of bacteria. At present this knowledge has not led to a successful method of combating those diseases, but we can hardly doubt that it will ultimately do so. We are warranted in this belief by the fact that the disease known as 'splenic fever' in cattle, and 'malignant pustule,' or anthrax, in man, has likewise been shown to be due to the action of a special kind of bacterium, and that this knowledge has, in the hands of MM. Toussaint and Pasteur, led to a treatment, in relation to this disease, similar to that of vaccination in relation to small-pox. By cultivation a modified growth of the anthrax parasite is obtained, which is then used in order to inoculate cattle and sheep with a mild form of the disease, such inoculation having the result of rendering the cattle and sheep free from the attacks of the severe form of disease, just as vaccination or inoculation with cow-pox protects man from the attack of the deadly small-pox. One other case I may call to mind, in which knowledge of the presence of bacteria as the cause of disease has led to successful curative treatment. A not uncommon affliction is inflammation of the bladder, accompanied by ammoniacal decomposition of the urine. Microscopical investigation has shown that this ammoniacal decomposition is entirely due to the activity of a bacterium. Fortunately, this bacterium is at once killed by weak solutions of quinine, which can be injected into the bladder without causing any injury or irritation. This example appears to have great importance; because it is the fact that many kinds of bacteria are not killed by solutions of quinine, but require other and much more irritant poisons to destroy their life, which could not be injected into the bladder without causing disastrous effects. Since some bacteria are killed by one poison, and some by another, it becomes a matter of the keenest interest to find out all such poisons; and possibly among them may be some which can be applied so as to kill the bacteria which produce phthisis, erysipelas, glanders, anthrax, and other scourges of humanity, whilst not acting injuriously upon the body of the victim in which these infinitesimal parasites are doing their deadly work. In such ways as this, biology has turned the toy 'magnifying-glass' of the last century into a saver of life and health.

No less has the same agency revolutionized the thoughts of men in every branch of philosophy and speculation. The knowledge of the growth of the chick from the egg, and of other organisms from similarly constituted beginnings, has been slowly and continuously gained by prodigious labor, extending

over generation after generation of students who have occupied the laboratories, and lived on the stipends, provided by the governments of European states, — not English, but chiefly German. It is this history of the development of the individual animal and plant from a simple homogeneous beginning to a complex heterogeneous adult, which has furnished the starting-point for the wide-reaching doctrine of evolution. It is this knowledge, coupled with the knowledge of the myriad details of structure of all kinds of animals and plants, which the faithful occupants of laboratories, and the guardians of biological collections, have, in the past hundred years, laboriously searched out, and recorded. It is this which enabled Darwin to propound, to test, and to firmly establish his theory of the origin of species by natural selection, and finally to bring the origin, development, and progress of man also into the area of physical science. I have said enough, in referring only to two very diverse examples of the far-reaching consequences flowing from the discoveries of single-minded investigators in biological science, to remind my hearers that in the domain of biology, as in other sciences, the results attained by those who have labored simply to extend our knowledge of the structure and properties of living things, in the faith that every increase of knowledge will ultimately bring its blessing to humanity, have, in fact, led with astonishing rapidity to conclusions affecting most profoundly both the bodily and the mental welfare of the community.

We who know the beneficent results which must flow more and more from the labors of those who are able to create new knowledge of living things, or, in other words, are able to aid in the growth of biological science, must feel something more than regret, — even indignation, — that England should do so small a proportion of the laborious investigation which is necessary, and is being carried on for our profit by other nationalities. It must not be supposed, because we have had our Harvey and our Darwin, our Hunter and our Lister, that therefore we have done, and are doing, all that is needful in the increase of biological science. The position of this country in relation to the progress of science is not to be decided by the citation of great names.

We require to look more fully into the matter than this. The question is, not whether England has produced some great discoverers, or as many as any other nationality, but whether we might not, with advantage to our own community and that of the civilized world generally, do far more in the field of scientific investigation than we do.

It may be laid down as a general proposition, to which I know of no important exception, that scientific discovery has only been made by one of two classes of men; namely, (1) those whose time could be devoted to it in virtue of their possessing inherited fortunes; (2) those whose time could be devoted to it in virtue of their possessing a stipend or endowment especially assigned to them for that purpose.

Now, it is a very remarkable fact that in England, far more than in any other country, the possessors of

private fortunes have devoted themselves to scientific investigation. Not only have we, in all parts of the country, numerous *dilettanti*,¹ who, especially in various branches of biology, do valuable work in continually adding to knowledge, quietly pursuing their favorite study without seeking to reach to any great eminence, but it is the fact that many of the greatest names of English discoverers in science are those of men who held no professional position designed to maintain an investigator, but owed their opportunity simply to the fact that they enjoyed a more or less ample income by inheritance. Thus, Harvey possessed a private fortune, Darwin also, and Lyell. Such, also, is true of some of the English naturalists, who more recently have most successfully devoted their energies to research. Those who wish to defend the present neglect of the government and of public institutions to provide means for the carrying on of scientific research in this country are accustomed to declare as a justification for this neglect, that we do very well without such provision, inasmuch as the cultivation of science here flourishes in the hands of those who are in a position of pecuniary independence. The reply to this is obvious. If those few of our countrymen who by accident are placed in an independent position show such ability in the prosecution of scientific research, how much more would be effected in the same direction, were the machinery provided to enable those also who are *not* accidentally favored by fortune to enter upon the same kind of work! The number of wealthy men who have distinguished themselves in scientific research in England is simply evidence that there is a natural ability and liking for such work in the English character, and is a distinct encouragement to those who have it in their power to do so, to offer the opportunity of devoting themselves to research to a larger number of the members of the community. It is impossible to doubt that there are hundreds of men amongst us who have as great capacity for scientific discovery as those whom fortune has favored with leisure and opportunity. It cannot be doubted, that, were the means provided to enable even a proportion of such men to give themselves up to scientific investigation, great discoveries, of no less importance to the world than those relative to the causes of disease, and the development of living things from the egg, — which I have cited, — would be made as a direct consequence of their activity; whereas now we must wait until, in due course of time, these discoveries shall be made for us in the laboratories of Germany, France, or Russia.

It should further be pointed out, that it is altogether a mistake to suppose that the existence amongst us of a few very eminent men is any evidence that we are contributing largely to the hard work of careful study and observation, which really forms the material upon which the conclusions of eminent discoverers are based. You will find in every depart-

ment of biological knowledge, that the hard work of investigation is being carried on by the well-trained army of German observers. Whether you ask the zoölogist, the botanist, the physiologist, or the anthropologist, you will get the same answer: it is to German sources that he looks for new information; it is in German workshops that discoveries, each small in itself, but gradually leading up to great conclusions, are daily being made. To a very large extent, the business of those who are occupied with teaching or applying biological science in this country consists in making known what has been done in German laboratories. Our English students flock to Germany to learn the methods of scientific research; and to such a state of weakness is English science reduced, for want of proper nurture and support, that, even on some of the rare occasions when a capable investigator of biological problems has been required for the public service, it has been necessary to obtain the assistance of a foreigner trained in the laboratories of Germany.

Let me now briefly explain what are the arrangements, in number and in kind, which exist in other countries, for the purpose of promoting the advancement of biological science, which are wanting in this country.

In the German empire, with a population of 45,000,000, there are twenty-one universities. These universities are very different from any thing which goes by the name in this country. Amongst its other arrangements, devoted to the study and teaching of all branches of learning and science, each university has five institutes, or establishments, devoted to the prosecution of researches in biological science. These are respectively the physiological, the zoölogical, the anatomical, the pathological, and the botanical. In one of these universities of average size, each of the institutes named consists of a spacious building containing many rooms fitted as workshops, provided with instruments, a museum, and, in the last instance, with an experimental garden. All this is provided and maintained by the state. At the head of each institute is the university professor respectively of physiology, of zoölogy, of anatomy, of pathology, or of botany. He is paid a stipend by the state, which, in the smallest university, is as low as £120, but may be in others as much as £700, and averages, say, £400 a year. Considering the relative expenditure of the professional classes in the two countries, this average may be taken as equal to £800 a year in England.¹ Besides the professor, each institute has attached to it, with salaries paid by the state, two qualified assistants, who, in course of time, will succeed to independent positions. A liberal allowance is also made to each institute, by the state, for the purchase of instruments, material for study, and for the pay of servants; so that the total expenditure on professor, assistants, laboratory service, and

¹ I use this word in its best and truest sense, and would refer those who have been accustomed to associate with it some implication of contempt to the wise and appreciative remarks of Goethe on '*dilettanti*.'

¹ From the fact that the salaries of judges, civil servants, military and naval officers, parsons, and schoolmasters, as also the fees of physicians and lawyers, are in Germany even less than half what is paid to their representatives in England, I think that we are justified in making this estimate.

maintenance, averages £800 a year for each institute, reaching as much as £2,000 or £3,000 a year in the larger universities. It is the business of the professor, in conjunction with his assistants and the advanced students, who are admitted to work in the laboratories free of charge, to carry on investigations, *to create new knowledge* in the several domains of physiology, zoölogy, anatomy, pathology, and botany. It is for this that the professor receives his stipend, and it is on his success in this field of labor that his promotion to a more important or better paid post in another university depends. In addition to and irrespective of this part of his duties, each professor is charged with the delivery of courses of lectures, and of elementary instruction to the general students of the university; and for this he is allowed to charge a certain fee to each student, which he receives himself. The total of such fees may, in the case of a largely attended university and a popular subject, form a very important addition to the professorial income; but it is distinctly to be understood that such payment by fees is only an *addition* to the professor's income, quite independent of his stipend, and of his regular occupation in the laboratory: it is paid from a separate source, and for a separate object. There are thus in the German empire more than 100 such institutes devoted to the prosecution of biological discovery, carried on at an annual cost to the state of about £80,000, equal to about £160,000 in England, providing posts of graduated value for 300 investigators, some of small value, sufficient to carry the young student through the earlier portion of his career, whilst he is being trained and acting as the assistant of more experienced men; others forming the sufficient but not too valuable prizes which are the rewards of continuous and successful labor.

In addition to these university institutes, there are in Germany such special laboratories of research, with duly salaried staff of investigators, as the Imperial sanitary institute of Berlin, and the large museums of Berlin, Bremen, and other large towns, corresponding to our own British museum of natural history.

Moreover, we must be careful to note, in making any comparison with the arrangements existing in England, that there are, in addition to the universities in Germany, a number of other educational institutions, at least equal in number, which are known as polytechnic schools, technical colleges, and agricultural colleges. These furnish posts of emolument to a limited number of biological students, who give courses of instruction to their pupils; but they have not the same arrangements for research as the universities, and are closely similar to those colleges which have been founded of late years in the provincial towns of England, such as Bristol, Nottingham, and Leeds. The latter are sometimes quoted by sanguine persons, who are satisfied with the neglected condition of scientific training and research in this country, as really sufficient and adequate representatives of the German universities. As a matter of fact, the excellent English colleges in question do not present any thing at all comparable to the ar-

rangements of a German university, and are, in respect of the amount of money which is expended upon them, the number of their teaching-staff, and the efficiency of their laboratories, inferior not merely to the smallest German university, but inferior to many of the technical schools of that country.

Passing from Germany, I would now ask your attention for a moment to an institution which is supported by the French government, and which — quite irrespective of the French university system, which is not, on the whole, superior to our own — constitutes one of the most effective arrangements, in any European state, for the production of new knowledge. The institution to which I allude is the Collège de France in Paris, — co-existing there with the Sorbonne, the École de médecine, the École normale, the Jardin des plantes, and other state-supported institutions, — in which opportunity is provided for those Frenchmen who have the requisite talent to pursue scientific discovery in the department of biology, and in other branches of science. I particularly mention the Collège de France, because it appears to me that the foundation of such a college in London would be one of the simplest and most direct steps that could be taken towards filling, in some degree, the void from which English science suffers. The Collège de France is divided into a literary and a scientific faculty. Each faculty consists of some twenty professors. Each professor in the scientific faculty is provided with a laboratory and assistants (as many as four assistants in some cases), and with a considerable allowance for the expenses of the instruments and materials required in research. The personal stipend of each professor is £400, which has been increased by an additional £100 a year in some cases from the government department charged with the promotion of higher studies. The professors in this institution, as in the German universities, when a vacancy occurs, have the right of nominating their future colleague, their recommendation being accepted by the government. The professors are not expected to give any elementary instruction, but are directed to carry on original investigations, in prosecuting which, they may associate with themselves pupils who are sufficiently advanced to join in such work; and it is further the duty of each professor to give a course of forty lectures in each year, upon the results of the researches in which he is engaged. There are at present, among the professors of the Collège de France, four of the most distinguished among contemporary students of biological science, — Professor Brown-Sequard, Professor Marey, Professor Balbiani, and Professor Ranvier. Every one who is acquainted with the progress of discovery in physiology, minute anatomy, and embryology, will admit that the opportunities afforded to these men have not been wasted. They have, as the result of the position in which they have been placed, produced abundant and most valuable work, and have, in addition, trained younger men to carry on the same line of activity. It was here, too, in the Collège de France, that the great genius of Claude Bernard found the necessary conditions for its development.

Let us now see how many and what kind of institutions there are in England devised so as to promote the making of new knowledge in biological science. Most persons are apt to be deceived in this matter by the fact that the terms 'university,' 'professorship,' and 'college' are used very freely in England in reference to institutions which have no pecuniary resources whatever, and which, instead of corresponding to the German arrangements which go by these names, are empty titles, neither backed by adequate subsidy of the state nor by endowment from private sources.

In England, with its 25,000,000 inhabitants, there are only four universities which possess endowments and professoriates; viz., Oxford, Cambridge, Durham, and the Victoria (Owens college). Besides these, which are variously and specially organized each in its own way, there are the London colleges (University and King's), the Normal school of science at South Kensington, and various provincial colleges, which are, to a small and varying extent, in possession of funds which could be or are used to promote scientific research. Amongst all these variously arranged institutions, there is an extraordinarily small amount of provision for biological research. In London there is one professorship only, that at the Normal school of science, which is maintained by a stipend paid by the state, and has a laboratory and salaried assistants similarly maintained, in connection with it. The only other posts in London which are provided with stipends intended to enable their holders to pursue researches in the domain of biological science, are the two chairs of physiology and of zoölogy at University college, which, through the munificence of a private individual,¹ have been endowed to the extent of £300 a year each. To these should be added, in our calculation, certain posts in connection with the British museum of natural history and the Royal gardens at Kew, maintained by the state; though it must be remembered that a large part of the expenditure in those institutions is necessarily taken up in the preservation of great national collections, and is not applicable to the subvention of investigators. We may, however, reckon about six posts, great and small, in the British museum, and four at Kew, as coming into the category which we have in view. In London, then, we may reckon approximately some fourteen or fifteen subsidized posts for biological research. In Oxford there fall under this category the professorship of anatomy and his assistant, that of physiology, that of zoölogy, that of botany. The Oxford professorships are well supported by endowment, averaging £700 or £800 a year; but they are inadequately provided with assistants, as compared with corresponding German positions. Whilst Oxford has thus five posts, Cambridge has at present the same number, though the stipends are of less average value. In regard to Durham, it does not appear that the biological professorships (which have their seat in the Newcastle college of science) are

supported by stipends derived from endowment: they fall under another category, to which allusion will be made below, of purely teaching positions, supported by the fees paid for such teaching by pupils. The Victoria university (Owens college, Manchester) supports its professors of physiology, anatomy, zoölogy, botany, and pathology, 'by means partly of endowment, partly of pupils' fees. By the provision of adequate laboratories, and of salaries for assistants to each professor, and of student-fellowships, Owens college gives direct support to original investigation. We may reckon five major and eight minor posts as dedicated to biological research in this college. Altogether, then, we have fifteen positions in London and twenty-three in the provinces (taking assistantships and professorships and curatorships together), — a total of thirty-eight in all England, with its 25,000,000 inhabitants, as against the three hundred in Germany, with 45,000,000 inhabitants. In proportion to its population (leaving aside the consideration of its greater wealth), England has only about one-fourth of the provision for the advancement of biological research which exists in Germany.

It would not be fair to reckon in this comparison the various biological professorships in small colleges recently created, and paid to a small extent by stipends derived from endowments in the provincial towns of England: for the holders of these chairs are called upon to teach a variety of subjects; for instance, zoölogy, botany, and geology combined. And not only is the devotion of the energies of their teaching-staff to scientific discovery not contemplated in the arrangement of these institutions, but, as a matter of fact, the large demands made on the professors in the way of teaching must deprive them of the time necessary for any serious investigation. Such posts, in the fact that neither time, assistants, nor proper laboratories are provided to enable their holders to engage in scientific research, are school-masterships rather than professorships, as the word is used in German universities.

One result of the exceedingly small provision of positions in England, similar to those furnished by the German university system, and of the irregular, uncertain character of many of those which do exist, is, that there is an insufficient supply of young men willing to enter upon the career of zoölogist, botanist, physiologist, or pathologist, as a profession. The number of posts is too small to create a profession, i.e., an avenue of success; and consequently, whereas in Germany there is always a large body of new men ready to fill up the vacancies as they occur in the professorial organization, in England it very naturally does not appear to our university students as a reasonable thing to enter upon research as a profession, when the chances of employment are so few, and far between.

Before stating, as I propose to do, what appears to me a reasonable and proper method of removing, to some extent, the defect in our national life due to the want of provision for scientific research, I will endeavor to meet some of the objections which are

¹ Mr. Jodrell.

usually raised to such views as those which I am advocating. The endowment of research by the state, or from public funds of any kind, is opposed on various grounds. One is, that such action on the part of the government is well enough in continental states, but is contrary to the spirit of English statecraft, which leaves scientific as well as other *enterprise* to the individual initiative of the people. This objection is based on error, both as to fact and theory. It is well enough to leave to individual effort the conduct of such enterprises as are remunerative to the parties who conduct them; but it is a mistake to speak of scientific research as an 'enterprise' at all. The mistake arises from the extraordinary pertinacity with which so-called 'invention' is confounded with the discovery of scientific truth. New knowledge in biological or other branches of science cannot be sold: it has no marketable value. Koch could not have sold the discovery of the bacterium of phthisis for as much as sixpence, had he wished to do so. Accordingly, we find that there is not, and never has been, any tendency among the citizens of this country to provide for themselves institutions for the manufacture of an article of so little pecuniary value to the individual who turns it out as is new knowledge. On the other hand, as a matter of fact, the providing of means for the manufacture of that article is not only not foreign to English statecraft, but is largely, though not largely enough, undertaken by the English state. The Royal observatories, the British museum, the Royal gardens at Kew, the Geological survey, the government grant of £4,000 a year to the Royal society, the £300 or £400 a year (not a large sum) expended through the medical officer of the privy council upon the experimental investigation of disease, are ample evidence that such providing of means for creating new knowledge forms part of the natural and recognized responsibilities of the British government. Such a responsibility clearly is recognized in this country, and does fall, according to the present arrangement of things, upon the central government. What we have to regret is, that those who temporarily hold the reins of government fail to perceive the lamentable inadequacy of the mode in which this responsibility is met.

A second objection which is made to the endowment of research by public funds, or by other means, such as voluntary contributions, is this: it is stated that men engaged in scientific research ought to *teach*, and thus gain their livelihood. It is argued, in fact, that there is no need whatever to provide stipends or laboratories for researchers, since they have only to stand up and teach in order to make income sufficient to keep them and their families, and to provide themselves with laboratories. This is a very plausible statement, because it is the fact that some investigators have also been excellent lecturers, and have been able to make an income by teaching, whilst carrying on a limited amount of scientific investigation. But neither by teaching in the form of popular lectures, nor by teaching university or professional students who desire, as a result, to pass some examination-

test, is it possible, where there is a fair field and no favor, for a man to gain a reasonable income, and at the same time to leave himself time and energy to carry on original investigations in science.

In some universities, such as those of Scotland, the privilege of conferring degrees of pecuniary value to their possessors becomes a source of income to the professors of the university. They are, in fact, able to make considerable incomes, independently of endowment, by compelling the candidates for degrees to pay a fee to each professor in the faculty for the right of attending his lectures, and of presentation to the degree: consequently teaching here appears to be producing an income which may support a researcher. In reality, it is the acquisition of the university degree, and not necessarily the teaching, for which the pupil pays his fee. Where the teacher is unprotected by any compulsory regulations (such as that which requires attendance on his lectures, and fee-payment on the part of the pupils), it is *impossible* for him to obtain such an income, by teaching for one hour a day, as will enable him to devote the rest of the day to unremunerative study and investigation, for the following reason. Other teachers, equally satisfactory as teachers, will enter into competition with him, without having the same intention of teaching for one hour only, and of carrying on researches for the rest of the day. They will contemplate teaching for six hours a day, and they will accordingly offer to those who require to be taught, either six hours' teaching for the same fee which the researcher charges for one, or one hour for a sixth part of that fee: consequently the unprotected researcher will find his lecture-room deserted. Pupils will naturally go to the equally good teacher who gives more teaching for the same fee, or the same teaching for a less cost. And no one can say that this is not as it should be. The university pupil requires a certain course of instruction, which he ought to be able to buy at the cheapest rate. It does not seem to be doing justice to the pupil, to compel him to form one of a class consisting of some hundreds of hearers, where he can obtain but little personal supervision or attention from the teacher, whereas, if he had the free disposal of his fee, he might obtain six times the amount of attention from another teacher. This arrangement does not seem to be justifiable, even for the purpose of providing the university professor with an income, and leisure to pursue scientific research. The student's fee should pay for a given amount of teaching at the market value; and he has just cause of complaint, if, by compulsory enactments, he is taxed to provide the country with scientific investigation.

Teaching must, in all fairness, ultimately be paid for as teaching; and scientific research must be provided for out of other funds than those extracted from the pockets of needy students, who have a reasonable right to demand, in return for their fees, a full modicum of instruction and direction in study.

In the German universities, the professor receives a stipend which provides for him as an investigator. He also gives lectures, for which he charges a fee;

but no student is compelled to attend those lectures as a condition of obtaining his degree. Accordingly, independent teachers can and do compete with the professor in providing for the students' requirements in the matter of instruction. As a consequence, the fees charged for teaching are exceedingly small, and the student can feel assured that he is obtaining his money's worth for his money. He is not compelled to pay any fee to any teacher as a condition of his promotion to the university degree. In a German university, if the professor in a given subject is incompetent, or the class overcrowded, the student can take his fee to a private teacher, and get better teaching. All that is required of the candidate, as a condition of his promotion to the doctor's degree, is that he shall satisfy the examination-tests imposed by the faculty, and produce an original thesis.

Unless there be some such compelling influence as that obtaining in the Scotch universities, enabling the would-be researcher to gather to him pupils and fees without fear of competition, it seems impossible that he should gain an income by teaching, whilst reserving to himself time and energy for the pursuit of scientific inquiry. It is thus seen that the necessity of endowment, in some form or another, to make provision for scientific research, is a reality, in spite of the suggestion that teaching affords a means whereby the researcher may readily provide for himself. The simple fact is, that a teacher can only make a sufficient income by teaching, on the condition that he devotes his whole time and energy to that occupation.

Whilst I feel called upon to emphatically distinguish the two functions, — viz., that of *creating new knowledge*, and that of *distributing existing knowledge*, — and to maintain that it is only by arbitrary and undesirable arrangements not likely to be tolerated, or, at any rate, extended, at the present day, that the latter can be made to serve as the support of the former, I must be careful to point out that I agree most cordially with those who hold that it is an excellent thing for a man who is engaged in the one to give a certain amount of time to the other. It is a matter of experience, that the best teachers of a subject are, *ceteris paribus*, those who are actually engaged in the advancement of that subject, and who have shown such a thorough understanding of that subject as is necessary for making new knowledge in connection with it. It is also, in most cases, a good thing for the man engaged in research to have a certain small amount of change of occupation, and to be called upon to take such a survey of the subject in connection with which his researches are made, as is involved in the delivery of a course of lectures, and other details of teaching. Though it is not a thing to be contemplated, that the researcher shall sell his instruction at a price sufficiently high to enable him to live by teaching, yet it is a good thing to make teaching an additional and subsidiary part of his life's work. This end is effected in Germany by making it a duty of the professor (already supported by a stipend) to give some five or six lectures a week during the academical session, for which he is paid

by the fees of his hearers. The fees are low, but are sufficient to be an inducement; and, inasmuch as the attendance of the students is not compulsory, the professor is stimulated to produce good and effective lectures at a reasonable charge, so as to attract pupils who would seek instruction from some one else, if the lectures were not good, or the fees too high. Indeed, in Germany this system works so much to the advantage of the students, that the private teachers of the universities at one time obtained the creation of a regulation forbidding the professors to reduce their fees below a certain minimum; since, with so low a fee as some professors were charging, it was impossible for a private teacher to compete. This state of things may be compared with much advantage with the condition of British universities. In these we hear, from one direction, complaints of the high fees charged, and of the ineffective teaching given by the professoriate; and in other universities, where no adequate fees are allowed to the professors as a stimulus to them to offer useful and efficient teaching, we find that the teaching has passed entirely out of their hands into those of college tutors and lecturers. The fact is, that a satisfactory relation between teaching and research is one which will not naturally and spontaneously arrange itself. It can hardly be said to exist in any British university or college, but the method has been thought out and carried into practice in Germany. It consists in giving a competent researcher a stipend, and a laboratory for his research work, and then requiring him to do a small amount of teaching, remunerated by fees proportionate to his ability and the pains which he may take in his teaching. If you pay him a fixed sum as a teacher, or artificially insure the attendance of his class, instead of letting this part of his income vary simply and directly with the attractiveness of his teaching, you will find as the result that (with rare exceptions) he will not give effective and useful teaching. He will naturally tend to do the minimum required of him in a perfunctory way. On the other hand, if you leave him without stipend as a researcher, dependent on the fees of pupils for an income, he will give all his time and energies to teaching: he will cease to do any research, and become, *pro tanto*, an inferior teacher.

A third objection which is sometimes made to the proposition that scientific research must be supported and paid for as such, is the following: it is believed by many persons that a man who occupies his best energies in scientific research can always, if he choose, make an income by writing popular books or newspaper articles in his spare hours; and, accordingly, it is gravely maintained that there is no need to provide stipends, and the means of carrying on their work, for researchers. To do so, according to this view, would be to encourage them in an exclusive reticence, and to remove from them the inducement to address the public on the subject of their researches, by which the public would lose valuable instruction.

This view has been seriously urged, or I should not here notice it. Any one who is acquainted with the sale of scientific books, and the profits which either

author or publisher makes by them, knows that the suggestion which I have quoted is ludicrous. The writing of a good book is not a thing to be done in leisure moments; and such as have been the result of original research have cost their authors often years of labor, apart from the mere writing. Mr. Darwin's books, no doubt, have had a large sale; but that is due to the fact, apart from the exceptional genius of the man who wrote them, that they represent some thirty or more years of hard work, during which he was silent. There is not a sufficiently large public interested in the progress of science to enable a researcher to gain an income by writing books, however great his literary facility. A schoolbook or classbook may now and then add more or less to the income of a scientific investigator; but he who becomes the popular exponent of scientific ideas, except in a very moderate and limited degree, must abandon the work of creating new knowledge. The professional *littérateur* of science is as much removed by his occupation from all opportunity of serious investigation as is the professional teacher who has to consume all his time in teaching. Any other profession—such as the bar, medicine, or the church—is more likely to leave one of its followers time and means for scientific research than is that of either the popular writer or the successful teacher.

We have, then, seen that there is no escape from the necessity of providing stipends and laboratories for the purpose of creating new knowledge, as is done in continental states, if we are agreed that more of this new knowledge is needed, and is among the products which a civilized community is bound to turn out, both for its own benefit and for that of the community of states, which give to and take from one another in such matters.

There are some who would finally attack our contention by denying that new knowledge is a good thing, and by refusing to recognize any obligation, on the part of England, to contribute her share to that common stock of increasing knowledge by which she necessarily profits. Among such persons are those who would prohibit altogether the pursuit of experimental physiology in England, and yet would not and do not hesitate to avail themselves of the services of medical men whose power of rendering those services depends on the fact that they have learned the results obtained by the experiments of physiologists in other countries or in former times. In reference to this strange contempt and even hatred of science, which undoubtedly has an existence among some persons of consideration even at the present day, I shall have a few words to say before concluding this address. I have now to ask you to listen to what seems to me to be the demand which we should make, as members of a British association for the advancement of science, in respect of adequate provision for the creation of new knowledge in the field of biology in England.

Taking England alone, as distinct from Scotland and Ireland, we require, in order to be approximately on a level with Germany, forty new biological institutes, distributed among the five branches of physiology, zoölogy, anatomy, pathology, and botany, —

forty, in addition to the fifteen which we may reckon (taking one place with another) as already existing. The average cost of the buildings required would be about £4,000 for each, giving a total initial expenditure of £160,000; the average cost of stipends for the director, assistants, and maintenance, we may calculate at £1,500 annually for each, or £60,000 for the forty, — equal to a capital sum of £2,000,000. These institutes should be distributed in groups of five — eight groups in all — throughout the country. One such group would be placed in London (which is at present almost totally destitute of such arrangements), one in Bristol, one in Birmingham, one in Nottingham, one in Leeds, one in Newcastle, one in Ipswich, one in Cardiff, one in Plymouth, — in fact, one in each of the great towns of the kingdom where there is at present, or where there might be with advantage, a centre of professional education and higher study. The first and the most liberally arranged of these biological institutes — embracing its five branches, each with its special laboratory and staff — should be in London. If we can have nothing else, surely we may demand, with some hope that our request will eventually obtain compliance, the formation in London of a College of scientific research similar to that of Paris (the Collège de France). It is one of the misfortunes and disgraces of London, that, alone amongst the capitals of Europe, with the exception of Constantinople, it is destitute of any institution corresponding to the universities and colleges of research which exist elsewhere.

Either in connection with a properly organized teaching university, or as an independent institution, it seems to me a primary need of the day that the government should establish in London laboratories for scientific research. Two hundred and fifty years ago Sir Thomas Gresham founded an institution for scientific research in the city of London. The property which he left for this purpose is now estimated to be worth three millions sterling. This property was deliberately appropriated to other uses, by the Corporation of the city of London and the Mercers' company, about a hundred years since, with the consent of both Houses of Parliament. By this outrageous act of spoliation these corporations, who were the trustees of Gresham, have incurred the curse which he quaintly inserted in his will in the hope of restraining them from attempts to divert his property from the uses to which he destined it. 'Gresham's curse' runs as follows: "And that I do require and charge the said Corporations and chief governors thereof, with circumspect Diligence and without long Delay, to procure and see to be done and obtained, as they will answer the same before Almighty God; (for if they or any of them should neglect the obtaining of such Licenses or Warrants, which I trust cannot be difficult, nor so chargeable, but that the overplus of my Rents and Profits of the Premises hereinbefore to them disposed, will soon recompense the same; because to soe good Purpose in the Commonwealth, no Prince nor Council in any Age, will deny or defeat the same. And if conveniently by my Will or other Convenience, I might assure it, I would not leave it

to be done after my death, then the same shall revert to my heirs, whereas I do mean the same to the Commonwealth, and then THE DEFAULT THEREOF SHALL BE TO THE REPROACH AND CONDEMNATION OF THE SAID CORPORATIONS AFORE GOD"). I confess that I find it difficult to see how the present representatives of the corporations who perverted Gresham's trust are to escape from justly deserving the curse pronounced against those corporations, unless they conscientiously take steps to restore Gresham's money to its proper uses. Let us hope that Gresham's curse may be realized in no more deadly form than that of an act of parliament repealing the former one which sanctioned the perversion of Gresham's money. Such a sequel to the report of the commission which has recently inquired into the proceedings of the corporation and companies of the city of London is not unlikely.

Whilst we should, I think, especially press upon public attention the need for an institute of scientific research in London, and indicate the source from which its funds may be fitly derived, we must also urge the foundation of other institutes in the provinces, upon the scale already sketched; because it is only by the existence of numerous posts, and of a series of such posts, — some of greater and some of less value, the latter more numerous than the former, — that any thing like a professional career for scientific workers can be constructed. It is especially necessary to constitute what I have termed 'assistantships,' that is, junior posts, in which younger men assist, and are trained by, more experienced men. Even in the few institutions which do already exist, additional provision of this kind is what is wanted more than any thing else, so that there may be a progressive career open to the young student, and a sufficient field of trained investigators from which to select in filling up the vacancies in more valuable positions.

I am well aware that it will be said that the scheme which I have proposed to you is gigantic and almost alarming in respect of the amount of money which it demands. One hundred and sixty thousand pounds a year for biology alone must seem, not to my hearers, but to those who regard biology as an amusing speculation, — that is to say, who know little or nothing about it, — an extravagant suggestion. Unfortunately, it is also true that such persons are very numerous, — in fact, constitute an overwhelming majority of the community; but they are becoming less numerous every day. The time will come, it seems possible, when there will be more than one member of the government who will understand and appreciate the value of scientific research. There are already a few members of the House of Commons who are fully alive to its significance and importance.

We may have to wait for the expenditure of such a sum as I have named, and possibly it may be derived ultimately from local rather than imperial sources, though I do not see why it should be; yet I think it is a good thing to realize *now* that this is what we ought to expend in order to be on a level with Germany. This apparently extravagant and unheard of

appropriation of public money is *actually made every year in Germany.*

I think it is well to put the matter before you in this definite manner; because I have reason to believe that even those whom we might expect to be well informed in regard to such matters are not so, and, as a consequence, there is not that keen sense of the inferiority and inadequacy of English arrangements in these matters which one would gladly see actuating the conduct of English statesmen. For instance: only a few years ago, when speaking at Nottingham, the present prime-minister, who has taken an active part in re-arranging our universities, and has, it is well known, much interest in science and learning, stated that £27,000, the capital sum expended on the Nottingham college of science, was a very important contribution to the support of learning in this country, amounting, as he said he was able to state from the perusal of official documents, to as much as one-third of what was spent in Germany during the past year upon her numerous universities, which were so often held up to England as an example of a well-supported academical system. Now, I do not think that Mr. Gladstone can ever have had the opportunity of considering the actual facts with regard to German universities: for he was in this instance misled by the official return of expenditure on a single university, namely, that of Strasburg; the total annual expenditure on the twenty-one German universities being, in reality, about £800,000, by the side of which a capital sum of £27,000 looks very small indeed. I cannot but believe, that if the facts were known to public men, in reference to the expenditure incurred by foreign states in support of scientific inquiry, they would be willing to do something in this country of a sufficient and statesmanlike character. As it is, the concessions which have been made in this direction appear to me to be in some instances not based upon a really comprehensive knowledge of the situation. Thus, the tentative grant of £4,000 a year from the treasury to the Royal society of London appears to me not to be a well-devised experiment in the promotion of scientific research by means of grants of money; because it is on too small a scale to produce any definite effect, and because the money cannot be relied upon from year to year as a permanent source of support to any serious undertaking.

The Royal society most laboriously and conscientiously does its best to use this money to the satisfaction of the country, but the task thus assigned to it is one of almost insurmountable difficulty. In fact, no such miniature experiments are needed. The experiment has been made on a large scale in Germany, and satisfactory results have been obtained. The reasonable course to pursue is to benefit by the experience, as to details and methods of administration, obtained in the course of the last sixty years in Germany, and to apply that experience to our own case.

It is quite clear that 'the voluntary principle' can do little towards the adequate endowment of scientific research. Ancient endowments belonging to the country must be applied thereto, or else local or imperial taxes must be the source of the necessary support.

Seeing that the results of research are distinctly of imperial and not of local value, it would seem appropriate that a portion of the imperial revenue should be devoted to their achievement. In fact, as I have before mentioned, the principle of such an application of public money has long been admitted, and is in operation.

Whilst voluntary donations on the part of private persons can do little to constitute a fund which shall provide the requisite endowment for the scheme of biological institutes which I have sketched (not to mention those required for other branches of science), yet those who are interested in the progress of scientific investigation may, by individual effort, do something, however little, towards placing research in a more advantageous position in this country. Supposing it were possible, as I am sanguine enough to believe that it is, to collect in the course of a year or two, from private sources, a sum of £20,000 for the maintenance of a biological laboratory and staff: it would be necessary, in expending so limited a sum, to aim at the provision of something which would be likely to produce the largest and most obvious results in return for the outlay, and to benefit the largest number of scientific observers in this department.

I believe that it is the general opinion among biologists, that there could be no more generally useful institution thus set in operation than a biological laboratory upon the seacoast, which, besides its own permanent staff of officers, would throw open its resources to such naturalists as might from time to time be able to devote themselves to researches within its precincts. There is no such laboratory on the whole of the long line of British coast. At Naples there is Dr. Dohrn's celebrated and invaluable laboratory, which is frequented by naturalists from all parts of the world; at Trieste, the Austrian government supports such a laboratory; at Concarneau, Roscoff, and Villefranche, the French government has such institutions; at Beaufort, in North Carolina, the Johns Hopkins university has its marine laboratory; and at Newport Professor Alexander Agassiz has arranged a very perfect institution also for the study of marine life. In spite of the great interest which English naturalists have always taken in the exploration of the sea and marine organisms; in spite of the fact that the success, and even the existence, of our fisheries industries, to a large extent depend upon our gaining the knowledge which a well-organized laboratory of marine biology would help us to gain, — there is actually no such institution in existence.

This is not the occasion on which to explain precisely how, and to what extent, a laboratory of marine zoölogy might be of national importance. I hope to see that matter brought before the section during the course of our meeting. But I may point out now, that though it appears to me that the great need for biological institutes, to which I have drawn your attention, can *not* be met by private munificence, and must, in the end, be arranged for by the continued action of the government in carrying out a policy to which it has for many years been committed, and which has been approved by conservatives and liberals

alike, yet such a special institution as a laboratory of marine biology, serving as a temporary workshop to any and all of our numerous students of the important problems connected with the life of marine plants and animals, might very well be undertaken from private funds. Should it be possible, on the occasion of this meeting of the British association in Southport, to obtain some promise of assistance towards the realization of this project, I think we shall be able to congratulate ourselves on having done something, though small, perhaps, in amount, towards making better provision for biological research, and therefore something towards the advancement of science.

In conclusion, let me say, that, in advocating to-day the claim of biological science to a far greater measure of support than it receives at present from the public funds, I have endeavored to press that claim chiefly on the ground of the obvious utility to the community of that kind of knowledge which is called biology. I have endeavored to meet the opposition of those who object to the interference of the state, wherever it may be possible to attain the end in view without such interference, but who profess themselves willing to see public money expended in promoting objects which are of real importance to the country, and which cannot be trusted to the voluntary enterprise arising from the operation of the laws of self-preservation, and the struggle for wealth. There are, however, it seems to me, further reasons for desiring a thorough and practical recognition by the state of the value of scientific research. There are not wanting persons of some cultivation, who have perceived and fully realized the value of that knowledge which is called science, and of its methods, and yet are anxious to restrain rather than to aid the growth of that knowledge. They find in science something inimical to their own interests, and accordingly either condemn it as dangerous and untrustworthy, or encourage themselves to treat it with contempt by asserting, that, 'after all, science counts for very little,' — a statement which is unhappily true in one sense, though totally untrue when it is intended to signify that the progress of science is not a matter which profoundly influences every factor in the well-being of the community. Amongst such people there is a positive hatred of science, which finds expression in their exclusion of it, even at this day, from the ordinary curriculum of public-school education, and in the baseless, though oft-repeated calumny, that science is hostile to art, and is responsible for all that is harsh, ugly, and repulsive in modern life. To such opponents of the advancement of science it is of little use to offer explanations and arguments. But we may, when we reflect on their instinctive hostility, and the misrepresentations of science and the scientific spirit which it leads them to disseminate, console ourselves by bringing to mind what science really is, and what truly is the nature of that calling in which a man who makes new knowledge is engaged.

They mock at the botanist as a pedant, and the zoölogist as a monomaniac; they execrate the physi-

ologist as a monster of cruelty, and brand the geologist as a blasphemer; chemistry is held responsible for the abomination of aniline dyes and the pollution of rivers, and physics for the dirt and misery of great factory towns. By these unbelievers, science is declared responsible for individual eccentricities of character, as well as for the sins of the commercial utilizers of new knowledge. The pursuit of science is said to produce a dearth of imagination, incapability of enjoying the beauty either of nature or of art, scorn of literary culture, arrogance, irreverence, vanity, and the ambition of personal glorification.

Such are the charges, from time to time, made by those who dislike science; and for such reasons they would withhold, and persuade others to withhold, the fair measure of support for scientific research which this country owes to the community of civilized states. Not in reply to these misrepresentations, but by way of contrast, I would here state what science seems to be to those who are on the other side, and how, therefore, it seems to them wrong to delay in doing all that the wealth and power of the state can do to promote its progress.

Science is not a name applicable to any one branch of knowledge, but includes all knowledge which is of a certain order or scale of completeness. All knowledge which is deep enough to touch the causes of things is science: all inquiry into the causes of things is scientific inquiry. It is not only co-extensive with the area of human knowledge, but no branch of it can advance far, without reacting upon other branches: no department of science can be neglected, without sooner or later causing a check to other departments. No man can truly say this branch of science is useful, and shall be cultivated, whilst this is worthless, and shall be let alone: for all are necessary; and one grows by the aid of another, and in turn furnishes methods and results assisting in the progress of that from which it lately borrowed.

We desire the increase and the support and the acceptance of science, not only because it has a certain material value, and enables men to battle with the forces of nature, and to turn them to account so as to increase both the intensity and the extension of healthy human life: that is a good reason, and for some persons, it may be, the only reason. But there is something to be said beyond this.

The pursuit of scientific discovery, the making of new knowledge, gratifies an appetite, which, from whatever cause it may arise, is deeply seated in man's nature, and, indeed, is the most distinctive of his properties. Man owes this intense desire to know the nature of things, smothered though it often be by other cravings which he shares with the brutes, to an inherited race-perception, stronger than the reasoning faculty of the individual. When once aroused, and in a measure gratified, this desire becomes a guiding passion. The instinctive tendency to search out the causes of things, gradually strengthening as generation after generation of men have stumbled and struggled in ignorance, has at last become an active and widely extending force: it has given rise to a new faith.

To obey this instinct—that is, to aid in the production of new knowledge—is the keenest and the purest pleasure of which man is capable, greater than that derived from the exercise of his animal faculties in proportion as man's mind is something greater and further developed than the mind of brutes. It is in itself an unmixed good, the one thing which commends itself as still 'worth while' when all other employments and delights prove themselves stale and unprofitable.

Arrogant and foolish as those men have appeared, who, in times of persecution, and in the midst of a contemptuous society, have, with an ardor proportioned to the prevailing neglect, pursued some special line of scientific inquiry, it is nevertheless true that in itself, apart from special social conditions, science must develop, in a community which honors and desires it before all things, qualities and characteristics which are the highest, the most human of human attributes. These are, firstly, the fearless love and unflinching acceptance of truth; hopeful patience; that true humility which is content not to know what cannot be known, yet labors and waits; love of Nature, who is not less, but more worshipped by those who know her best; love of the human brotherhood, for whom and with whom the growth of science is desired and effected.

No one can trace the limits of science, nor the possibilities of happiness, both of mind and body, which it may bring in the future to mankind. Boundless though the prospect is, yet the minutest contribution to the onward growth has its absolute and unassailable value,—once made, it can never be lost: its effect is forever in the history of man.

Arts perish, and the noblest works which artists give to the world. Art, though the source of great and noble delights, cannot create nor perpetuate: it embodies only that which already exists in human experience, whilst the results of its highest flights are doomed to decay and sterility. A vain regret, a constant effort to emulate or to imitate the past, is the fitting and laudable characteristic of art at the present day. There is, indeed, no truth in the popular partition of human affairs between science and art as between two antagonistic or even comparable interests; but the contrast which they present in points such as those just mentioned is forcible. Science is essentially creative: new knowledge—the experience and understanding of things which were *previously non-existent for man's intelligence*—is its constant achievement. And these creations never perish: the new is built on, and incorporates, the old; there is no turning back to recover what has lapsed through age; the oldest discovery is even fresher than the new, yielding in ever-increasing number new results, in which it is itself reproduced and perpetuated, as the parent in the child.

This, then, is the faith which has taken shape in proportion as the innate desire of man for more knowledge has asserted itself: namely, that there is no greater good than the increase of science; that through it all other good will follow. Good as science is in itself, the desire and search for it is even

better, raising men above vile things and worthless competitions, to a fuller life and keener enjoyments. Through it we believe that man will be saved from misery and degradation, not merely acquiring new material powers, but learning to use and to guide his life with understanding. Through science he will be freed from the fetters of superstition. Through faith in science he will acquire a new and enduring delight in the exercise of his capacities: he will gain a zest and interest in life such as the present phase of culture fails to supply.

In opposition to the view that the pursuit of science can obtain a strong hold upon human life, it may be argued, that on no reasonable ground can it appear a necessary or advantageous thing to the individual man to concern himself with the growth and progress of that which is merely likely to benefit the distant posterity of the human race. Our reply is, let those who contend for the reasonableness of human motives develop, if they can, any theory of human conduct in which reasonable self-interest shall be man's guide. We do not contend for any such theory. By reasoning we may explain and trace the development of human nature, but we cannot change it by any such process. It is demonstrably unreasonable for the individual man, guided by self-interest, to share the dangers and privations of his brother-man; and yet, in common with many lower animals, he has an inherited quality which makes it a pleasure to him to do so. It is unreasonable for the mother to protect her offspring, and yet it is the natural and inherited quality of mothers to derive pleasure from doing so. It is unreasonable for the half-starved poor to aid their wholly-starving brethren; and yet such compassion is natural and pleasurable to those who show it, and is the constant rule of life. Unreasonable though these things are, from the point of view of individual self-interest, yet they are done because to do them is pleasurable, to leave them undone a pain. The race has, as it were, in these respects, befooled the individual, and, in the course of evolution, has planted in him, in its own interests, an irrational capacity for taking pleasure in doing that which no reasoning in regard to self-interest could justify. As with these lower and more widely distributed instincts, shared by man with some lower social animals, so is it with this higher and more peculiar instinct, — the tendency to pursue new knowledge. Whether reasonable or not, it has, by the laws of heredity and selection, become part of us, and exists. Its operation is beneficial to the race. Its gratification is a source of keen pleasure to the individual, — an end in itself. We may safely count upon it as a factor in human nature. It is in our power to cultivate and develop it, or, on the other hand, to starve and distort it for a while, though to do so is to waste time in opposing the irresistible.

As day by day the old-fashioned stimulus to the higher life loses the dread control which it once exercised over the thoughts of men, the pursuit of wealth, and the indulgence in fruitless gratifications of sense, become to an increasing number the chief concerns of their mental life. Such occupations fail to satisfy

the deep desires of humanity: they become wearisome and meaningless, so that we hear men questioning whether life be worth living. When the dreams and aspirations of the youthful world have lost their old significance, and their strong power to raise men's lives, it will be well for that community which has organized in time a following of and a reverence for an ideal good, which may serve to lift the national mind above the level of sensuality, and to insure a belief in the hopefulness and worth of life. The faith in science can fill this place. The progress of science is an ideal good, sufficient to exert this great influence.

It is for this reason, more than any other (as it seems to those who hold this faith), that the progress and diffusion of scientific research, its encouragement and reverential nurture, should be a chief business of the community, whether collectively or individually, at the present day.

NOTES AND NEWS.

PURSUANT to the invitation already noted in *SCIENCE*, a number of gentlemen met in the library of the American museum of natural history in New-York City, on the 26th to 28th of September, and founded the American ornithologists' union. The membership consists of active, foreign, corresponding, and associate members. The active membership is limited to fifty residents of the United States and Canada; the foreign, to twenty-five non-residents of the United States and Canada; the corresponding, to one hundred residents of any country; the associate being composed of any number of residents of the United States and Canada. The officers of the union for the current year are, Mr. J. A. Allen, president; Dr. Elliott Coues and Mr. Robert Ridgway, vice-presidents; Dr. C. Hart Merriam, secretary and treasurer; Messrs. S. F. Baird, George N. Lawrence, H. W. Henshaw, and Montagu Chamberlain, councillors, — these nine officers constituting the council of the union. Dr. Coues presided over the convention, and continued in the chair in the absence of the president. Mr. Allen and Professor Baird, who were unable to be present, were added to the list of founders. After the discussion and adoption of a constitution, submitted by the committee of organization, and the election of officers, a large number of members were elected, raising the active and foreign membership nearly to the limit. The work of the union for the present year was laid out by the formation of committees, appointed by the chair, on the subjects of classification and nomenclature, of the distribution and migration of birds, of avian anatomy, of oölogy, and on the question of the eligibility or ineligibility of the European sparrow in America. The first-named committee, besides revising the current lists of North-American birds, is expected to consider the subject of zoölogical nomenclature at large; and its labors may result in the formation of a code of nomenclature applicable to other departments of zoölogy, as well as to ornithology. It consists of Messrs. Ridgway, Allen, Brewster, Henshaw, and Coues.